PHYTOPLANKTON POPULATIONS IN SEVERAL ICE-COVERED LAKES OF SOUTHERN ONTARIO

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By:

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SUMMARY

The quantity and composition of the phytoplankton in lakes of various trophic levels was investigated during and immediately following a period of ice-cover. Algal populations under ice were quite low in all lakes, probably as a result of light inhibition and a lack of support for heterotrophic and phagotrophic growth. Following the loss of ice-cover algal populations in eutrophic lakes increased up to 250 times and relationships between inorganic nitrogen, dissolved silicate, total phosphorus and algal responses suggest nitrogen to be the nutrient restricting this phytoplankton development. The pertinence of the results of this study to the development of taste and odour problems in water supplies during the winter months is discussed.

INTRODUCTION

Other than a few midwinter observations from certain Algonquin Park lakes (McCombie, 1942) very little information is available about phytoplankton populations of Ontario inland lakes during periods of ice cover. Data of other investigations however indicate that in this type of environment the quantities of algae which can exist can vary anywhere from a few cells per unit volume to the formation of an algal bloom (Birge and Juday, 1922; Chandler, 1942, 1944; Verduin, 1959; Wright, 1964; Rodhe et al, 1966; Billaud, 1968; Pennak, 1968).

To increase our knowledge about the quantity and composition of phytoplankton which exists in Ontario surface waters during the winter months, eight lakes representing various trophic levels were investigated from January to early May, 1968. These lakes, which include Kushog, Twelve Mile, Gull, Balsam, Sturgeon, Buckhorn, Clear and Rice, all lie within the Trent River drainage basin in southern Ontario and have been studied with respect to nutrient-phytoplankton relationships during 1967 (Christie, 1968).

MATERIAL AND METHODS

Each lake was examined five times beginning in January at approximately the same location as that used in the previous study (Christie, 1968) except in May when samples were obtained at the outfall. Sampling was accomplished by passing a 40-ounce bottle through a column of water which was twice the depth of water transparency as determined using a 25 cm secchi disc. Water temperature in each lake was recorded at a depth of one metre below the surface in February, April and May.

Characterization of water samples for various chemical and physical parameters were carried out according to standard methods (American Public Health Assoc., 1965).

Samples for phytoplankton analysis were immediately treated with Lugol's IKI solution and subsequently concentrated by sedimentation from 1000 ml to 25 ml. The algal content was estimated by observing between 150-200 organisms per sample in a Sedgewick-Rafter cell and expressing the results in Areal Standard Units/millilitre (ASU/ml) (American Public Health Assoc., 1965). One Areal Standard Unit is equivalent to an area of 400 square microns.

RESULTS

Chemistry and Physics

Average values of the various chemical and physical parameters determined from samples of each lake during the study are summarized in Table I. Variations with time in the concentrations of total phosphorus, inorganic nitrogen and dissolved silicate are portrayed in more detail in Figures 1A, 1B. Secchi disc readings obtained each time as a measure of water transparency are listed in Table II.

Snow cover on the lakes, although never excessively deep (Table III), and except for two instances of slush at Kushog and Rice lakes, appeared to be of a dry consistency which had been compacted by wind action. In February a crust of snow sufficiently strong enough to support a man's weight was also evident on most of the lakes. Ice thickness increased as the winter progressed (Table III) except at Buckhorn in February. Just why this decrease in thickness occurred is rather difficult to explain although the combination of a warm spell a few days earlier accompanied perhaps by an increase in water movement may have been contributory. On all lakes long cracks in the ice surface which had refilled and frozen were apparent as well as some buckling of the ice

TABLE I

AVERAGE VALUES OF VARIOUS CHEMICAL AND PHYSICAL PARAMETERS

ASSOCIATED WITH EACH LAKE

		Kushog	Twelve Mile	Gull	Balsam	Sturgeon	Buckhorn	Clear	Rice
Calcium	(mg/l)	4.4	5.8	8.0	19.8	35.8	37.2	34.2	39.4
Magnesium	(mg/l)	1.2	1.2	1.6	2.4	3.8	3.0	3.4	4.2
Potassium	(mg/l)	0.64	1.00	0.94	1.12	1.16	1.02	1.02	1.12
Sodium	(mg/l)	1.3	1.9	2.1	2.8	3.3	2.6	2.7	2.8
Iron (total)	(mg/l)	0.24	0.13	0.13	0.10	0.17	0.15	0.13	0.13
Phosphorus (total)	(mg/l)	0.030	0.018	0.016	0.013	0.025	0.028	0.022	0.035
Ammonia as N	(mg/l)	0.14	0.13	0.09	0.09	0.20	0.14	0.13	0.14
Nitrate as N	(mg/l)	0.14	0.15	0.15	0.09	0.17	0.12	0.21	0.10
Organic Nitrogen	(mg/l)	0.28	0.18	0.22	0.22	0.32	0.28	0.29	0.35
Sulphate	(mg/l)	10.6	8.8	10.4	10.6	15.8	14.6	16.4	15.2
Chloride	(mg/l)	2.0	1.6	1.4	2.2	4.6	4.0	4.0	4.6
Silicate (dissolved)	(mg/l)	2.9	3.3	3.2	3.6	5.3	4.3	4.5	2.2
Alkalinity ($CaCO_3$)	(mg/l)	7.2	12.0	18.0	42.0	91.4	89.6	84.6	97.2
Hardness ($CaCO_3$)	(mg/l)	15.6	20.0	26.4	54.4	104.8	106.4	100.0	115.6
Total Dissolved Solids	(mg/l)	29.8	37.6	43.4	76.2	139.2	149.6	144.2	150.8
Phenol	(ug/l)	2.0	2.6	2.8	2.8	4.4	4.0	4.0	3.0
Conductivity	(μmhos/cm^3)	40.2	49.6	63.4	106.8	212.4	218.2	199.6	227.6
pH		7.1	7.2	7.3	7.6	7.8	7.9	7.9	8.2
Turbidity (standard units)		1.84	1.80	1.36	1.16	2.46	2.52	2.08	2.02

TABLE II

SECCHI DISC MEASUREMENTS OF THE LAKES

DURING THE STUDY (Metres)

	Jan.	Feb.	March	April	May
Kushog	1.5	1.5	4.0	3.0	4.0
Twelve Mile	2.7	3.0	3.5	5.0	5.0
Gull	3.0	2.5	4.0	5.0	4.0
Balsam	3.0	3.0	4.0	3.0	5.5
Sturgeon	3.0	2.5	2.0	2.0	2.0
Buckhorn	3.0	2.5	2.0	2.0	2.0
Clear	3.1	2.0	3.5	3.0	2.5
Rice	3.0	1.0	2.0	2.0	2.0

TABLE III

SNOW DEPTH AND ICE THICKNESS (cm)

		Jan.	Feb.	March
Kushog	Snow	*15	8	8
	Ice	25	46	61
Twelve Mile	Snow	13	8	8
	Ice	30	46	60
Gull	Snow	3	3	5
	Ice	30	45	56
Balsam	Snow	13	2	5
	Ice	38	53	61
Sturgeon	Snow	3	8	5
	Ice	38	51	56
Buckhorn	Snow	3	8	7
	Ice	30	15	46
Clear	Snow	10	5	7
	Ice	38	50	62
Rice	Snow	*13	5	5
	Ice	30	61	62

*Slush

along the shoreline. The upper portion of the ice profile typically appeared quite snowy and translucent transcending to a glass-like appearance as one approached the underlying water.

Water temperatures at a depth of 1 metre below either the ice or surface have been listed in Table IV.

TABLE IV

WATER TEMPERATURES ($^{\circ}C$) AT A DEPTH OF 1 METRE

	Feb.	April	May
Kushog	0.4	8.6	10.1
Twelve Mile	0.0	8.4	7.1
Gull	0.0	6.2	9.0
Balsam	0.2	10.2	11.0
Sturgeon	0.5	10.0	12.0
Buckhorn	0.1	12.1	12.5
Clear	0.0	10.0	10.3
Rice	0.6	11.3	12.0

Phytoplankton

Examination of the water samples obtained from these lakes during the period of ice cover show that the quantity of phytoplankton is quite low (Figures 1A, 1B), never exceeding a level of 100 ASU/ml and lying more typically in the range of 10 ASU/ml. The population during this period (Figures 2A, 2B), for the most part appears to be dominated by the Bacillariophyta or diatoms of which the most persistent members seem to be Asterionella, Fragilaria, Melosira and Tabellaria (Table V). Various flagellated forms including Dinobryon, Cryptomonas and Peridinium also appeared from time to time while the few Chlorophyta or green algae which were observed consisted principally of Ankistrodesmus and Scenedesmus. The Cyanophyta or bluegreens noted in January and February such as Anabaena, Aphanizomenon and Lyngbya were not apparent by March at which time the only form observed was Oscillatoria.

Following the break-up of the ice cover in mid-April the algal populations increased anywhere from 6 to 250 times, on the basis of ASU/ml, and were composed almost entirely of diatoms, Synedra and Cyclotella appearing in greater abundance.

Figure 1A. Relationships between the standing crop of algae and total phosphorus, inorganic nitrogen and dissolved silicate.

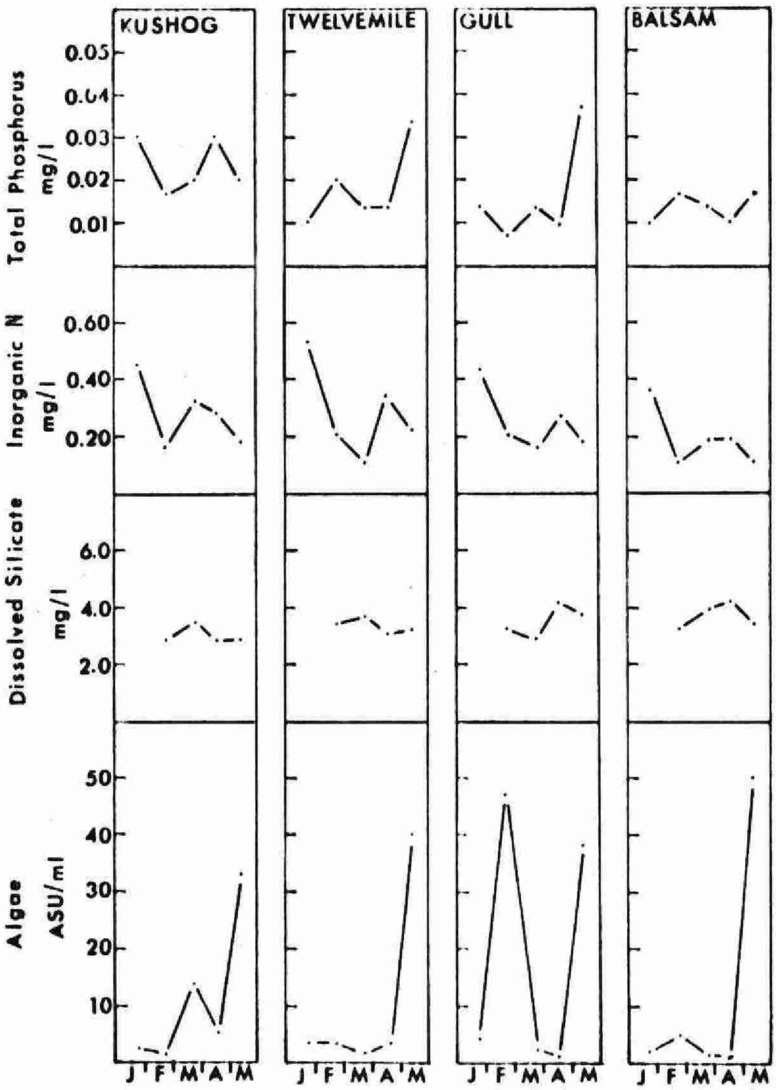

Figure 1B. Relationships between the standing crop of algae and total phosphorus, inorganic nitrogen and dissolved silicate.

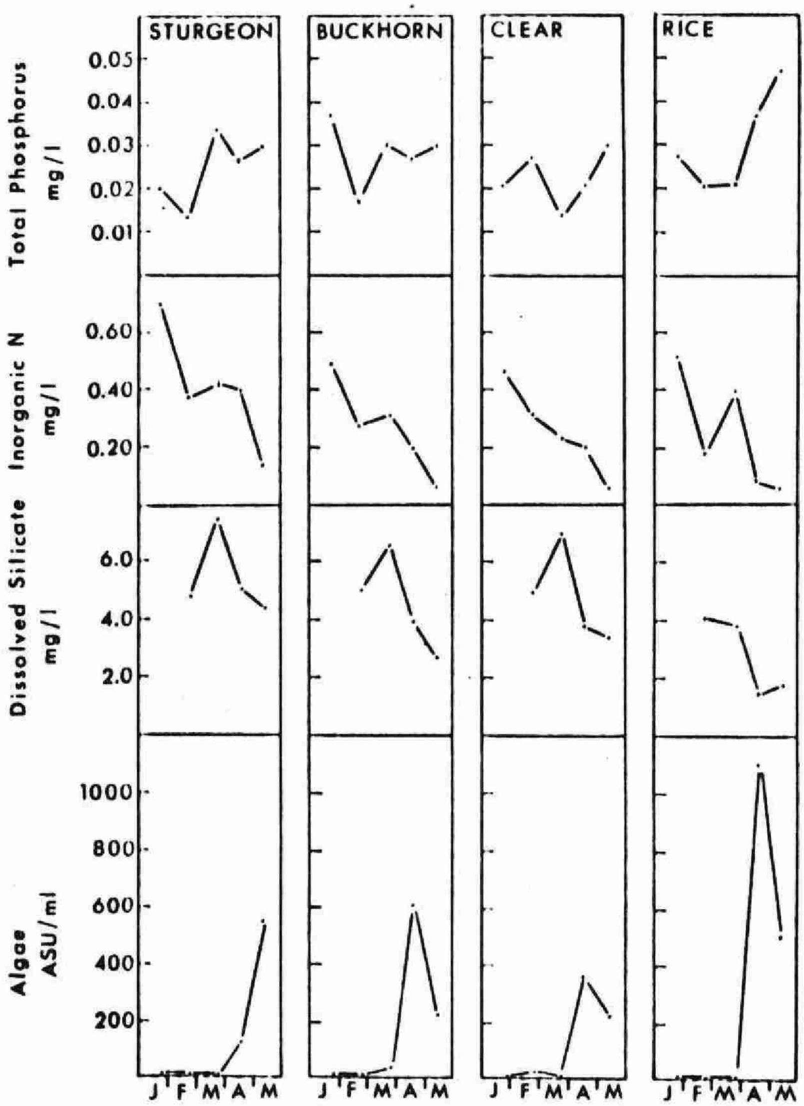

Figure 2A. Percentage Composition of Standing Crops of Phytoplankton by Division, based on ASU/1.

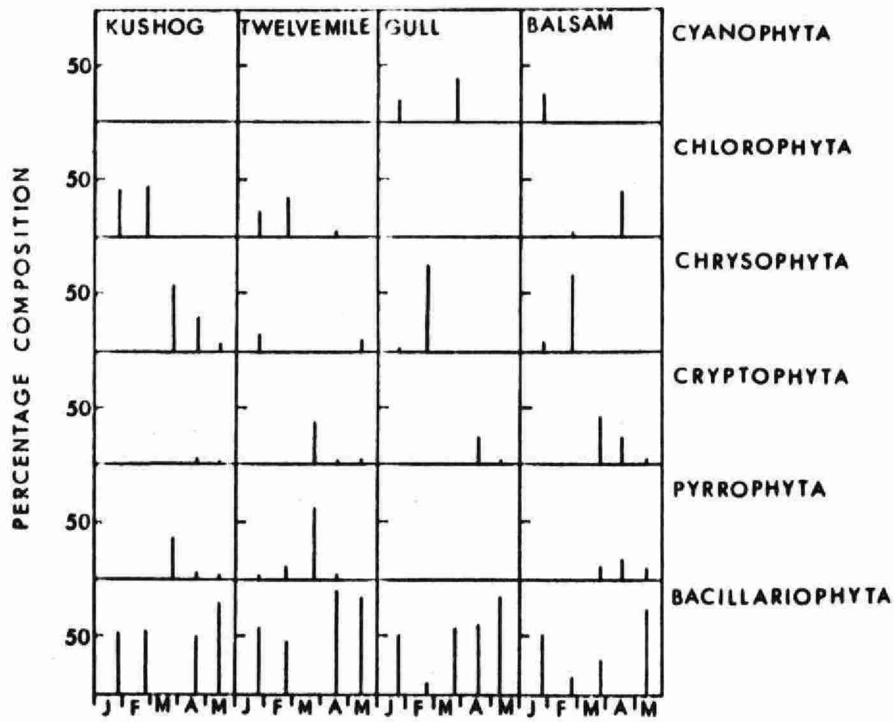

Figure 2B. Percentage Composition of Standing Crops of Phytoplankton by Division, based on ASU/1.

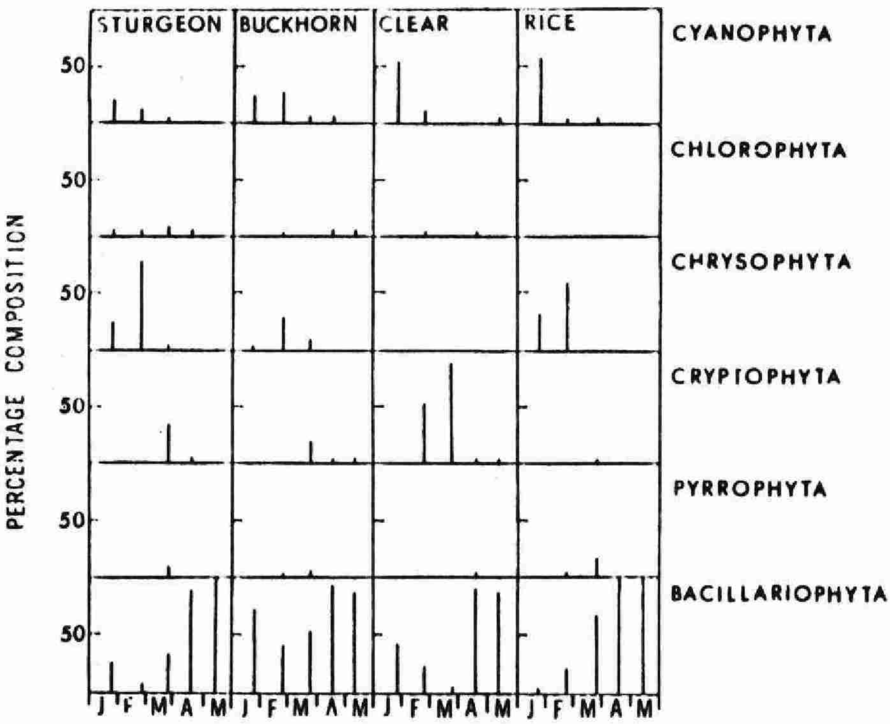

TABLE V

PHYTOPLANKTON OBSERVED DURING THE STUDY

CYANOPHYTA

Anabaena flos-aquae (Lyngb.) De Brebisson
Anabaena circinalis Rabenhorst
Aphanizomenon flos-aquae (L) Ralfs
Lyngbya sp.
Microcystis aeruginosa Kuetz.
Oscillatoria sp.

CHLOROPHYTA

Ankistrodesmus falcatus (Corda) Ralfs
Arthrodesmus sp.
Closterium sp.
Dictyosphaerium pulchellum Wood.
Pediastrum Boryanum (Turp.) Meneghini
Scenedesmus bijuga (Turp.) Lagerheim
Scenedesmus armatus (Chod.) G. M. Smith
Sphaerocystis Schroeteri Chodat
Staurastrum paradoxum Meyen

CHRYSOPHYTA

Dinobryon bavaricum Imhof
Dinobryon sertularia Ehrenberg
Synura uvella Schrenberg

CRYPTOPHYTA

Cryptomonas erosa Ehrenberg

PYRROPHYTA

Ceratium hirundinella (O.F. Muell.) Dujardin
Peridinium cinctum (Muell.) Ehrenberg

(Table V - cont'd)

BACILLARIOPHYTA

Asterionella formosa Hass.
Cyclotella bodanica Eulenstein
Cyclotella Meneghiniana Kützing
Fragilaria capucina Desm.
Fragilaria crotonensis Kitten
Melosira islandica O. Müller
Melosira varians Ag.
Navicula cuspidata Kützing
Navicula peregrina (Ehr.) Kützing
Stauroneis phoenicenteron Ehrenberg
Stephenodiscus niagare Ehrenberg
Synedra pulchella (Ralfs) Kützing
Synedra ulna (Nitsch) Ehrenberg
Tabellaria fenestrata (hyngb.) Kützing

DISCUSSION

The results of this study show (Figures 1A, 1B), as has been observed for example in other Ontario inland lakes (McCombie, 1942), that the quantities of phytoplankton present during a period of ice cover are extremely low. Examination of nutrient availability before and after the spring ice break-up in those lakes previously identified as eutrophic - Sturgeon, Buckhorn, Clear and Rice (Christie, 1968) - would suggest that the limited development of algae is not a result of a low aqueous mineral fertility (Figure 1B). As algal pulses approaching a bloom condition have been observed in ice-covered lakes, the low temperature of the environment (Table IV), although perhaps exerting a qualitative effect (Hutchinson, 1967), could not be considered to be acting as a deterent quantitatively (Chandler, 1942; Verduin, 1958; Billaud, 1968; Pennak, 1968). A comparison of the snow and ice thickness and composition with observations of Greenbank (1945) and Wright (1964) indicates that light penetration through the frozen cover of these lakes to the underlying water is extremely low, probably in the order of one percent of the incident radiation. Autotrophic or light dependent growth of algae below the ice is therefore inhibited due to

insufficient light. The low standing crops of phytoplankton (Figure 1B) would imply that the availability of dissolved organic materials which could support heterotrophic (nutrition dependent on organic matter for food) and phagotrophic (nutrition dependent on ingestion of microorganisms for food) development of phytoplankton, as suggested by Rodhe (1953), Wright (1964), Rodhe et al (1966) and Pennak (1968), is also quite minimal.

Following the break-up of the ice cover in mid-April, algal populations became composed almost entirely of diatoms (Figure 2A, 2B). In the eutrophic lakes this increase in diatoms was accompanied by a decrease in both inorganic nitrogen and dissolved silicate, although interestingly enough the total phosphorus levels increased, probably as a result of thermal mixing. As the dissolved silicate concentrations did not fall to a value of 0.4-0.5 mg/l, the suggested lower limit for diatom growth (Lund et al, 1963), algal responses at this time were more likely restricted by the decreasing availability of inorganic nitrogen. The absence of any dramatic upsurge of the algae in the other four lakes during this period is considered to be related more to the limited supply of inorganic carbon (Table I), discussed elsewhere (Christie, 1968), rather than due to the involvement of either nitrogen or silicate.

Although tastes and odours in water obtained from ice-covered sources have been reported (Iantosca and Snow, 1952; personal communication, Division of Research, OWRC), the two communities Bobcaygeon and Hastings which obtain their water from Sturgeon and Rice lakes respectively did not experience this type of problem during the study. In view of the mineral fertility of these two lakes however, the formation of a relatively transparent ice cover with no snow, which would allow a greater amount of light penetration, could result in the development of algal pulses similar to those noted in Lake Erie by Chandler (1942). Should the availability of organic substances which support heterotrophic and phagotrophic development of such algae as Cryptomonas and Ceratium (Wright, 1964; Rodhe et al, 1966) increase, greater quantities of phytoplankton might also be expected. However, at this time one can no more than speculate whether such algal responses could result in the formation of undesirable tastes and odours.

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